Detection of line shape parameters in normal and abnormal biological tissues

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Abstract

Doppler broadening technique is suggested to monitor the development of tumours. It depends on the sensitivity of positronium (Ps) annihilation parameters to the sub- microstructural changes in biological tissues. This technique uses high resolution HpGe detector to measure the lineshape parameters (S and W) in normal mice's mammary tissues and adenocarcinoma mammary tissues as a function of tumour growth. The results demonstrate that the central parameter (S) decreases and the wing parameter (W) increases as the tumour grow. It is found that the S parameter changes considerably with the distribution of voids which are affected by the tumour development. Therefore the present technique can successfully be employed to monitor the development of tumours.

Key words

Doppler broadening, lineshpe parameters, biological tissues.

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تحديد اعاليم الشكل الخطي في الانسجة البايلوجية الطبيعية و غير الطبيعية

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الخلاصة

اقترحت تقانة توسع دوبلر لمراقبة تطور عمر الورم حيث انها تعتمد على اعاليم فناء البوزترونيوم وحساسيتها بالنسبة للتغيرات التي تحدث في التراكيب الدقيقة للانسجة البايولوجية . أستخدم في هذه التقنية كاشف الجرمانيوم ذو ميز طاقي عالي لقياس أعاليم الشكل الخطي (S,W) في النسيج الطبيعي لانثى الفار في منطقة الغدد اللبنية وكذلك النسيج الغير الطبيعي (الورم) في نفس المنطقة كدالة لتطور عمر الورم. بينت النتائج أن المعلم المركزي (S) يتناقص بينما المعلم الجناح (W) يتزايد مع تطور عمر الورم ، ووجد ايضا أن المعلم (S) يتغير وبشكل كبير مع كيفية توزيع الفجوات التي تتاثر بعمر الورم . لذلك فأن هذه التقنية ممكن أن تستخدم وبنجاح لمراقبة تطور الاورام.

Introduction

The basic principle of Positron Annihilation Spectroscopy (PAS) lies on the fact that thee annihilation gamma photons carry information about the electronic environment in which the positron annihilates. The annihilation of positron with an electron is a unique feature of positron interaction in matter. In molecular substances a thermalized positron will either annihilates as a free particle or bind to an electron to form a positronium (Ps) and subsequently annihilates [1].

Ps can be visualized as an analog to the hydrogen atom, in which the proton is substituted by a positron, and thus can be considered as the lightest isotope of the hydrogen atom with half the usual reduced mass (m_o/2) [2].

The Ps atom can exist in two hyperfine structure states: with antiparallel electron and positron (para-positronium, p-Ps) and with parallel ones (ortho-positronium, o-Ps) [3,4]. The statistical weight of the triplet state o-Ps is three times as large as that of the singlet state p-Ps. Therefore, in normal cases, there is three times more o-Ps formed than p-Ps. The mean lifetime of p-Ps in free space is 0.125ns and two photons are emitted on its annihilation, while the mean lifetime of o-Ps in free space is 140 ns and three photons are emitted on annihilation [5].

Ps formation in molecular systems amounts to 20% to 70% of all positrons injected into the medium. This is higher than in metals and semi-conductors because of the higher concentration of imperfections and impurities and the lower electron density of molecular systems [4].

Doppler broadening technique was used to measure the energy of gamma rays using a high –purity germanium detector (HpGe). The two gamma photons emitted from Ps annihilation should have an energy of 511keV, the energy predicted by Einstein's E (eV) $=mc^2$. The motion of the annihilating pair causes a Doppler shift of this energy[6].

$$\Delta E\gamma = ½ \, c \, pZ \qquad (1)$$

where pZ is the longitudinal momentum component of the pair in the direction of the annihilation gamma emission. This causes the broadening of the 511keV annihilation line.

The Doppler effect describes how the frequency of a wave emitted from a moving source changes according to the relative motion between the source and the observer. Since the gamma photons emitted from Ps annihilations behave as waves, they also exhibit the Doppler Effect. The final energy spectra consist of the sum of the individual shifts from much annihilation, so the energy peak is broad [6]. Fig (1) shows the Doppler broadened peak resulting from the moving Ps.

The shape of the 511keV annihilation is characterized mainly by an S and W parameters. The central parameter S is defined as the ratio of the counts in the central region of the annihilation line to the total number of the counts in that line. In the same way, the wing parameter W is the relative fraction of the counts in the wing regions of the line (Fig 2). Due to the low momentum of valance electrons, the annihilation falls predominantly in the region of the S parameter. On the other hand, mainly core electrons have

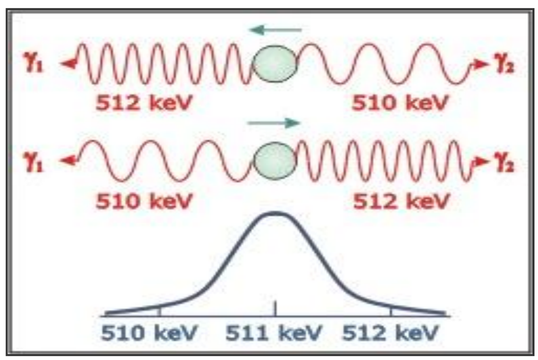

Fig.(1): Doppler broadened peak [6].

momentum values high enough to contribute to the W parameter. Therefore, S and W can be called the valance and core annihilation parameters, respectively [6]. The lineshape parameters have characteristic values for each material depending on the electron momentum distribution.

The Doppler-broadening spectrum demonstrates in Fig.(2). The *S* and *W parameters* are expresed as:

$$S=A_s/A_o \quad W=A_w/A_o \qquad (2)$$

where

A_s: the area of the central low-momentum part of the spectrum.
A_w: the area in the high-momentum region far from the center.
A_o : the area below the whole curve.

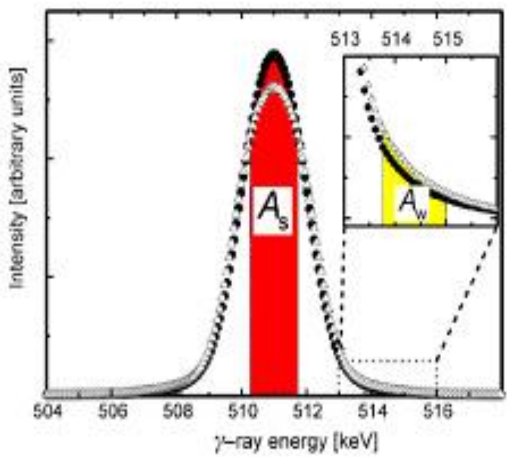

Fig. (2): Doppler broadening spectra. The lineshape parameters S and W are determined by the indicated areas A_S and A_W divided by the area below the whole curve.

The positron is a potentially sensitive probe to conformational changes of biological systems and to the transfer process of electrons [4]. Measurements in a biological system are concentrated on positronium formation because of its long lifetime and its high formation probability in a biological system.

Investigation of the sub-microstructural changes in biological tissues was first attempted in 1998 by the nuclear physics group at the Physics Department, College of Science, University of Baghdad using the lifetime technique [7-10].

The aim of the present work is the application of Doppler broadening technique in biological tissues to differentiation between normal and abnormal tissues (tumour). This is done by studying the changes of the lineshape (*S*,*W*) parameters.

Experimental Details

The motion of electron positron pair causes Doppler shifts in the energy of annihilation photons. Since experimental Doppler shift is strongly influenced by the detector resolution, a detector with a typical resolution around (2keV) at 1332 keV, is needed. A high purity germanium detector (HpGe) can be employed, which gives the appropriate energy resolution to study the Doppler shift [12].

A schematic diagram of the present spectrometer is shown in Fig. (3).

In this study, TENNLEK HpGe detector of p-type was used. Its energy resolution was measured to be (2.5keV) at the 1332keV gamma line of ^{60}Co.
^{22}Na radioisotope ($t_{1/2}$ 2.6 years) as a source for positrons was used, because of its relatively high positron yield (90.4%).

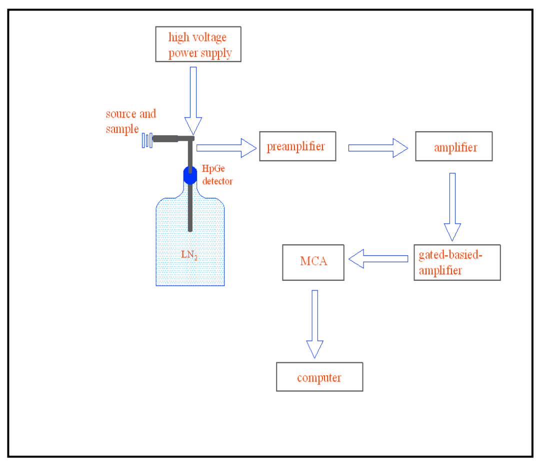

Fig.(3): Doppler broadening spectrometer.

Tumour Samples Preparation

Tumour specimens were prepared in the Iraqi Center for Cancer and Medical Genetics Research. The following method was used to induce the cancer cells in mice under study; Carcinoma was induced in female mice using cells aspirated from a mouse that has undergone spontaneous mammary adenocarcinoma. These cells were subcutaneously injected, after chemical and mechanical treatment, into the cervical zone through the neural femoral zone of the mice, by a dose of 0.25ml. Mice were chemically treated at the day of injection with two drugs to suppress their cellular and numeral immunity[13]. First drug (Novartspharma) was of a 30 mg /kgm/ day for a week time. The second (Methyl Prednisolon Sodium) was of a dose 30 mg/kgm on alternate days for a week time. The mice are put under surveillance for the appearance of cancer.

Doppler Spectra Analysis

The measured Doppler-broadening spectrum in a certain material is generally assumed to be well approximated by a single Gaussian distribution convoluted with the base line function (B.L). The analysis was done using RESOLUTION program which is based on this assumption, therefore the S and W parameters can be calculated for each spectrum. Fig. (4) shows the Doppler – broadening spectrum before and after using the RESOLUTION program.

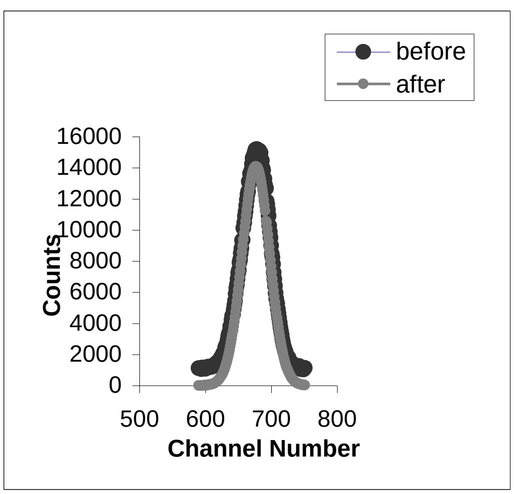

Fig. (4). The Doppler broadening spectrum before and after using the program.

Results and Discussion

A tumour is a group of cells that are continuously dividing and reproducing themselves without any orderly of specific purpose to give a rather loosely organized mass of cells. As tumour age increases, cell division increases, resulting in higher number of intercellular spaces, the volume of these spaces is decreased. O-Ps can be formed in these spaces. Table (1) summarizes the values of lineshape parameters at different ages of the tumour. In Fig. (5), the decrease in the *S* parameter values can be explained due to the increase in the number of tumour cells. As the age of the tumour increases, the number of tumour cells increases, these are located between the original cells, so reducing the volume of the voids which causes the decrease of *S* parameter values. Fig. (6) shows the increase of *W* parameter values as the tumour age increases due to the increase in the number of small voids. This is because; the localized positron in these small voids has more overlap with core electrons than free electrons leading to an increase in the core annihilation parameter.

Tumour age (day)	S - parameter	W - parameter
0 Normal (control)	0.6059±0.0010	0.0169±0.0001
8	0.5898±0.0010	0.0159±0.0001
14	0.5018±0.0009	0.0233±0.0002
22	0.4502±0.0008	0.0291±0.0002
26	0.4069±0.0008	0.0286±0.0002

Table (1): S and W parameters for normal and tumour tissues.

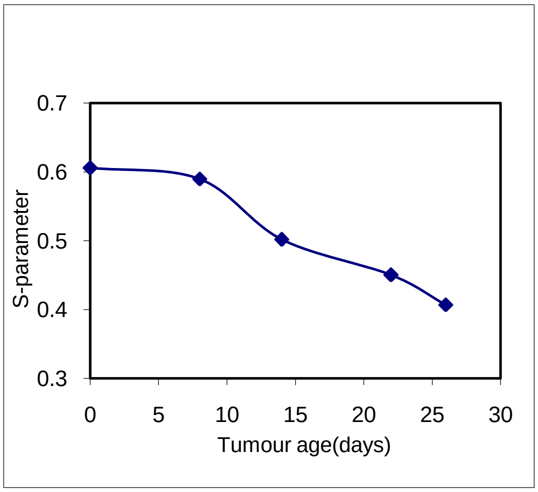

Fig. (5): The change in S parameter with the tumour age.

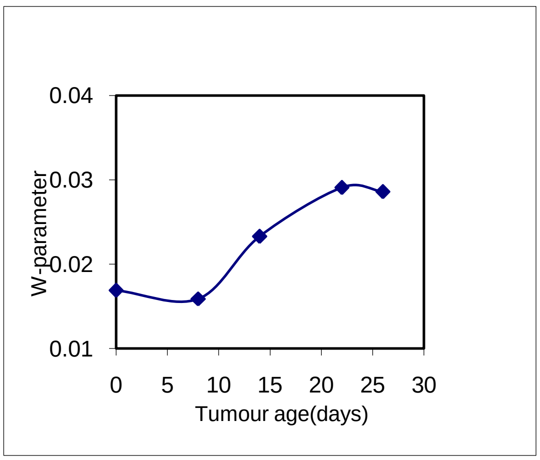

Fig. (6): The change in W parameter with the tumour age.

In a previous study performed by Elias et al. [11], lifetime parameters results (Fig. 7) as a function of tumour age showed that the o-Ps lifetime(τ_3) decreases as the tumour age increases. This is due to the decrease of the volume of voids. This decrease can be explained, as due to the increase in the number of cells, caused by the uncontrolled divisions of the cells tumour. It is obvious from these results, that the behavior of S and τ_3 with the tumour age are approximately the same.

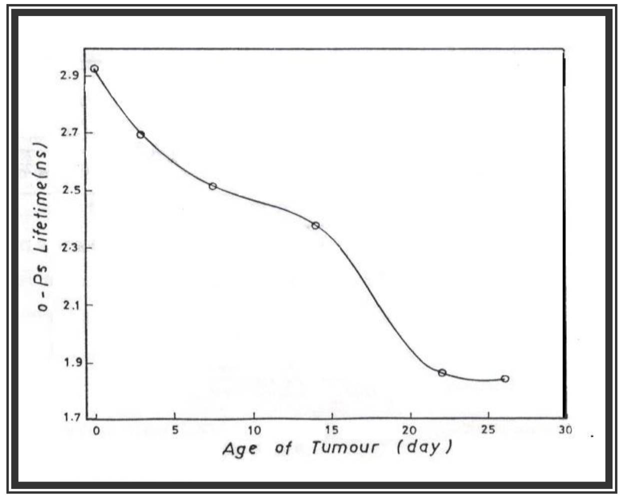

Fig. (7): The age of mice's tumour with o-Ps lifetime [10].

Conclusions

The results suggest that Doppler broadening technique can successfully be employed to distinguish between normal and abnormal tissues (tumour) through the small changes in S and W parameters. The results show that this technique appears to be a valuable method for obtaining information due to changes in tissues in the early stages of growth of tumour.

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